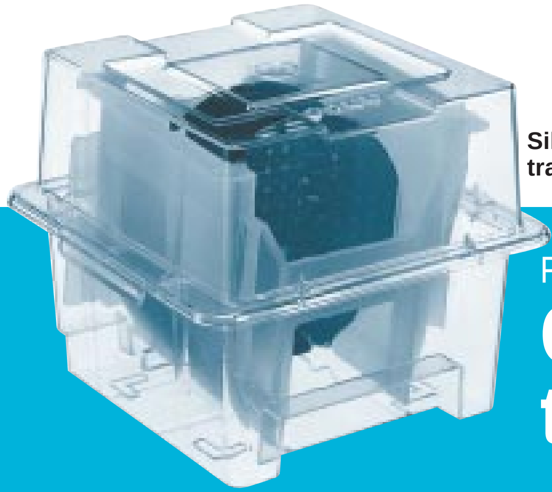
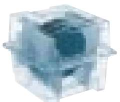


Silicon wafer storage and transport box

From Dust Reduction to Molecular Contamination Control

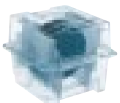
Clean Transport Technologies that Support Sony LSI Yields

- **Reducing organic contamination to 1/100 during silicon wafer transport and storage**
- **Inhibiting the native oxide film growth to under 0.5 nm during silicon wafer transport and storage**



Significance of Molecular Contamination Control

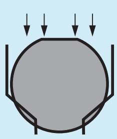
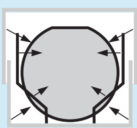
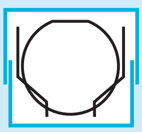
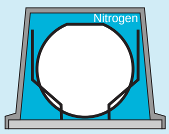
The cleanliness of the silicon wafers is an important factor that influences the ratio of defective devices (and thus the yield) in the manufacture of semiconductor devices. Due to the increasingly fine feature sizes in circuit patterns and the even thinner films used for gate oxide film, not only contaminant particles and transition metals, but even organic contamination is now of concern as a cause of defects that result in degradation of the dielectric breakdown voltage of the gate oxide film in MOS transistors.
Additionally, it is now known that the extremely thin native oxide film that is formed due to the oxygen and moisture in the air can cause defects that, by increasing the contact resistance, hinder both increasing the speed and reducing the power consumption of logic ICs. This oxide film can also lower the capacitance of memory capacitors. Since the defects caused by this molecular contamination, such as organic contamination and oxygen and moisture, are now causing problems in LSI manufacture, molecular contamination control is now required in devices with 0.25 µm and smaller feature sizes. Revolutions in wafer transport methods will become the key technology for assuring yields in the future. (See figure 1.)



Development of a Wafer Transport Box that Reduces Organic Contaminants

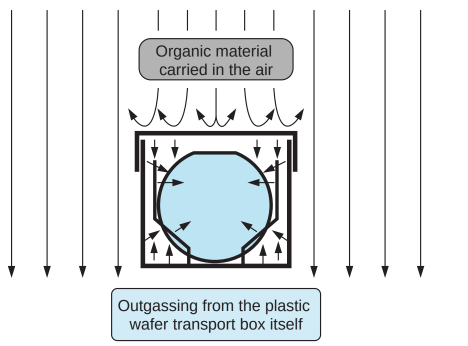
Clean rooms used in semiconductor device manufacturing are held in a dust-free (particle-free) state by the use of air filters. However, since large amounts of plastic materials (in the walls, ceilings, power supply cables), paints, caulking materials adhesives, and other organic materials are used, large amounts of volatile organic materials are carried in the air. Clean rooms are adequately clean with regards to microscopic particles, but have even worse conditions than normal offices for volatile organic materials.
Just as organic gasses given off by new materials in ordinary houses are now seen as problematic due to their influence on human health, organic gasses in the air have become a problem for device reliability in the LSI manufacturing process.
Since the LSI manufacturing process consists of repeatedly alternating between wet processes such as cleaning and dry processes such as CVD film formation, continuous operation is difficult and it is necessary to transport silicon wafers between process equipment stations. During this transport, since the wafers are exposed to the clean room atmosphere, volatile organic materials in the air are adsorbed onto the silicon wafer surface as organic contamination. This can be prevented by stroing the silicon wafers in protective transport boxes during transport.
However, we were then faced with the problem that the gaseous organic materials released from the wafer transport box itself were adsorbed by the wafers. (See figure 2.)
Conventional plastic transport boxes are made with little concern for gas emission. Rather, ease of formation is the major concern, and large quantities of additives such as plasticizers and antioxidants are used. Furthermore, no consideration is given to other organic impurities in the formation process. As a result, following formation, the transport boxes include large amounts of additives and impurities and emit large amounts of organic gasses. This results in large quantities of these being adsorbed onto the silicon wafers.
To resolve this problem, Sony developed the

Control of molecular contamination is increasingly needed with a shrinkage in device geometry

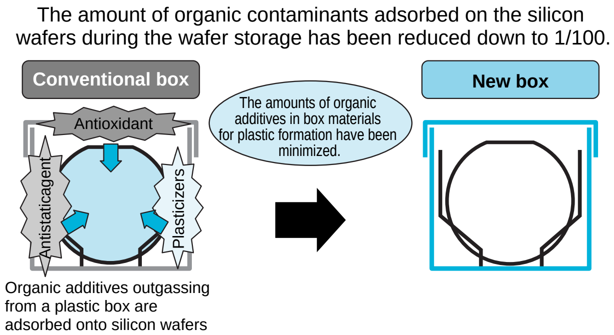
Year	Up to 1995	After 1995	After 1999	After 2002
Device	Up to 0.5 µm	0.35 µm	0.25 to 0.18 µm	Up to 0.13 µm
Desirable specifications	Particle free	Dopant contamination free	Organic contamination free	Native oxide free
Prevension of particle adhesion	○	○	○	○
Prevension of organic contamination adsorption	×	△	○	○
Prevension of native oxide growth	×	×	×	○
Wafer-storage methods (box/cassette)				
Cause of defects	Pattern defects	Variation of threshold voltage	Degradation of gate oxide integrity	Increase in sheet resistance

■ **Figure 1 Trend of Wafer-storage Methods**

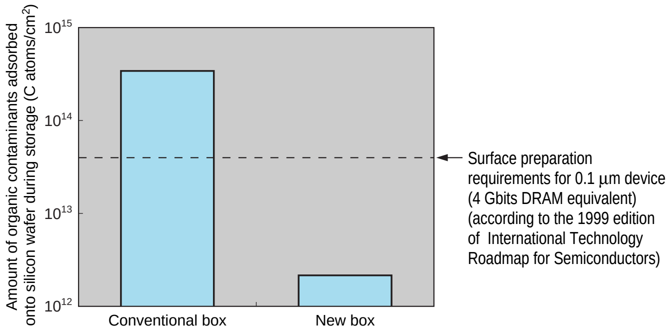
Although adsorption of organic material in the ambient air onto the wafers can be prevented by storing them in a box, the organic gas emitted by the box itself may be adsorbed by the wafers.



■ **Figure 2**



■ **Figure 3 Organic Contamination Free Wafer-storage Box**

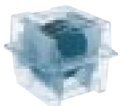


■ **Figure 4 Reducing Organic Contamination During Silicon Wafer Storage to 1/100 Previous Levels**

"Sony Organic-contamination Free BOX" silicon wafer storage and transport box, which reduces organic contamination radically.

As the first step in this development project, we carefully analyzed to what extent impurities became intermixed, from the raw materials (resins) to the final step of the manufacturing process. We used chemical analyzers capable of detecting minute amounts of organic materials on the wafer surface, and identified the gaseous organic materials that selectively adsorb onto a silicon wafer surface. Then we succeeded in radically suppressing the amount of these gasses released by controlling the additives and impurities in the raw materials themselves and in the manufacturing process. (See figure 3.) This resulted in reducing the organic materials adsorbed onto the wafer during transport to about 1/100 of previous levels, from 3.3×10^{14} to 2.2×10^{12} carbon atoms per square centimeter when this newly developed product is used.

By introducing this box into our most advanced line (a 0.25-micron process) we were able to obtain a stable value of essentially a 100% yield in the dielectric breakdown voltage characteristics of the gate oxide film formation process for MOS transistors. Thus we can now hope for improved yields not only in the manufacture of current devices (0.25 and 0.18 µm) but also of 0.1 µm class (corresponding to 4-Gbit DRAM) low-power consumption LSI and logic devices which are expected to be in volume production by the year 2005 according to the 1999 edition of International Technology Roadmap for Semiconductors. (See figure 4.) We are planning to introduce the use of this box first in the system LSI manufacturing line at Sony Kokubu Corp. and then in the manufacturing and test lines at Sony Nagasaki Corp. and the Sony Corp. Atsugi Technology Center.

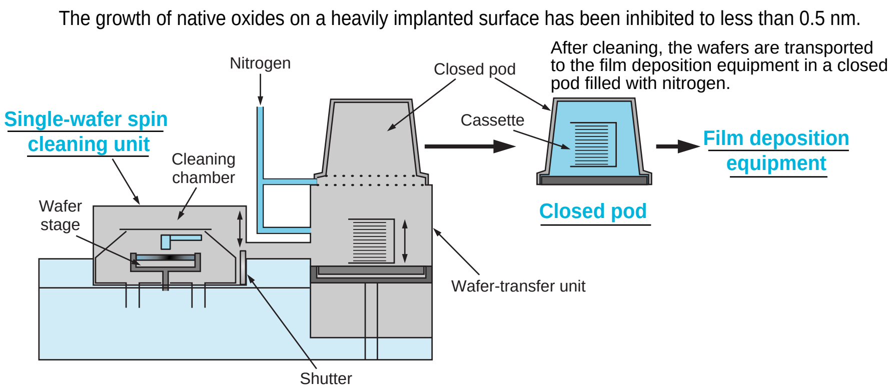


Development of Locally Clean Transport that can Prevent Organic Contamination and the Growth of Native Oxide Film

High-density impurity doping is performed in low-power consumption and high-speed logic LSIs and embedded DRAM fabrication, and special film deposition technology is used. As a result, not only organic materials, but even extremely thin native oxide film on the silicon surface can cause performance degradation such as increased contact resistance and reduced capacitances of memory capacitors. Therefore, in the future, transport techniques that protect the wafers not only from organic contamination but also from oxygen and moisture will be required as well.

It will be possible to completely protect wafers from oxygen and moisture by transporting them in a nitrogen atmosphere between manufacturing stations so that they are not exposed to the ambient air. (See figure 5.) To implement this, it will be necessary to completely seal the transport boxes and the process equipment. (See figure 1.) In addition, it will be possible to control both organic contamination and particles by controlled air flow and materials optimization. It may even be possible to create a semiconductor manufacturing system that does not require a clean room.

We now know from experiments such as those shown in figure 5 that it is possible to inhibit native oxide film growth to under 0.5 nm even in high density As-ion implanted wafers, which have an extremely fast native oxide film growth. We are currently developing a locally clean transport system that can prevent both organic contamination and native oxide film deposition. Sony Semiconductor's clean transport technology holds much promise for the future.



■ **Figure 5 Wafer-transport System Using a Closed Pod**